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## Brightest Cluster Galaxy Formation in Low-Redshift Galaxy Clusters

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**Abstract.** We present the composite luminosity function of a sample of 17 low-redshift galaxy clusters. Our luminosity functions have been measured for an inner region ( $r \leq r_{200}$ ) and an outer region ( $r_{200} \leq r \leq 2r_{200}$ ) centred on each Brightest Cluster Galaxy. The inner region luminosity function has a significantly flatter faint-end slope ( $\alpha_{inner} = -1.81 \pm 0.02$ ) than the outer region ( $\alpha_{outer} = -2.07 \pm 0.02$ ). These results are consistent with the hypothesis that a large fraction of dwarf galaxies near cluster centres are being tidally disrupted.

### 1. Introduction

Galaxy clusters provide a laboratory in which one can study the effects of galaxy formation and evolution over time. A detailed understanding of low-redshift clusters would furnish us with a benchmark in which to compare observations of higher redshift galaxy clusters. Cluster properties, such as luminosity functions, have the potential to yield valuable clues concerning the dynamical evolution of cluster galaxies, including the formation of Brightest Cluster Galaxies (BCGs).

Recent studies have concentrated on the merging process as an efficient way of creating BCGs (Merritt 1984; Schombert 1988). The formation of cD-like galaxies (we define cD galaxies as those with an extended halo (e.g., Schombert 1988) as well as those galaxies which are halo-dominated; Brown 1997) has been problematic since the merging process cannot account for the presence of an extended halo (Merritt 1984; Tremaine 1990).

From a survey of 45 low-redshift ( $0.04 \leq z \leq 0.18$ ) galaxy clusters, López-Cruz et al. 1997 proposed that the envelope of cD galaxies was created through the process of tidal disruption of dwarf galaxies (e.g., dwarf spheroidals). Evidence for this hypothesis was obtained by examining cluster luminosity functions (LFs). López-Cruz et al. (1997) found that clusters which contain a cD galaxy (Bautz Morgan types I, I-II; Rood-Sastry type “cd”) had flatter faint-end slopes (as parameterized by the Schechter function; Schechter 1976) than those which did not. Further support for this model was found by examining the dwarf-to-giant galaxy ratio (D/G), which was found to increase with increasing Bautz Morgan type (López-Cruz 1997).

## 2. Cluster Survey

In order to test the dwarf galaxy disruption model, we have conducted an imaging survey of low-redshift ( $0.02 \leq z \leq 0.04$ ) Abell clusters using the KPNO 0.9m telescope + 8k mosaic camera. We have obtained R band images for 27 clusters, of which a sub-sample of 11 were also observed in the B band. The 8k mosaic camera has a field-of-view of approximately one square degree and allows us to cover a region 2 to 4 Mpc in length, centred on each cluster.

The purpose of this survey is to test the dwarf galaxy disruption hypothesis by; 1) sampling cluster luminosity functions to a depth adequate to measure the faint-end slope, 2) measuring cluster LFs over a wide area in order to sample the LF as a function of cluster-centric radius, 3) determining the colour gradient of the BCG envelope and compare it to the radial colour gradient of the dwarf galaxy population, and 4) measuring the properties (LFs, spatial distributions, etc.) of morphologically selected galaxy sub-populations.

In this paper we concentrate on results based on the analysis of cluster luminosity functions (we use  $H_o = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$  and  $q_o = 0$  throughout).

### 2.1. Data Reductions and Photometry

Object detection, classification, and photometry was performed using PPP (Yee 1991). All bright, early-type galaxies were modeled and subtracted from their parent image using the same procedure as in Brown (1997). This allowed us to accurately measure the magnitudes of overlapping fainter galaxies which becomes a serious problem in the cluster core. Complete photometric catalogs of each cluster contain approximately 25,000 objects.

Since we do not have redshifts for every cluster galaxy, luminosity functions are created from the statistical subtraction of background galaxies. The background correction was determined by observing six controls fields, covering a total of six square degrees in area.

## 3. Luminosity Functions

The direct comparison of LFs for various surveys has been problematic. Many studies have relied on photographic plates and have compared cluster LFs measured using a different radial cutoff from the BCG (e.g., Lugger 1986). Since we expect that environment may have an influence on the overall galaxy population mixture (morphology-density relation; Dressler 1980), it is prudent to compare cluster LFs using the same dynamical radius. For this study, we have chosen to measure our LFs using the  $r_{200}$  radius (the radius within which the average density is 200 times the critical density). Since we lack radial velocity measurements, we use the correlation between  $r_{200}$  and Bgc (a richness indicator; Yee & López-Cruz 1999) as measured for the CNOC 1 cluster survey (Carlberg, Yee, & Ellingson 1997). We find that as cluster richness increases, the value of  $r_{200}$  also increases. Using this relationship, we can estimate a value of  $r_{200}$  for a given value of Bgc (which we can calculate from our photometry). In this way, we are able to make a more direct and robust comparison of cluster LFs.

In an effort to improve the signal-to-noise of cluster galaxies over foreground/background galaxies, we impose a colour criteria from which we select cluster members. Clus-

ter colour-magnitude diagrams clearly show the well known colour-magnitude relation (CMR; Baum 1959) for early-type cluster galaxies. The colour-magnitude diagram can reveal the presence of background contaminating clusters (López-Cruz 1997). We have used the colour-magnitude diagram to establish an upper envelope in which to reject redder background galaxies.

### 3.1. Composite Luminosity Function

We computed the composite LF for two radial bins centred on the BCG. The inner area was chosen to have a radius of  $r_{200}$ , and the outer bin had an inner radius of  $r_{200}$  and an outer radius  $2r_{200}$ . Clusters whose photometry was 100% complete to  $M_R = -16.0$ , and which had complete imaging out to a radius of  $2r_{200}$ , were included in the final sample. This sample consisted of 17 clusters, 7 of which have colour information which allowed us to impose a colour selection criteria based on the cluster’s CMR. All magnitudes were K corrected based on Coleman, Wu, & Weedman (1980) and corrected for galactic extinction (Burstein & Heiles 1982).

Individual cluster LFs were constructed through the statistical subtraction of background galaxy counts as measured from six control fields. The rejection criteria used for each cluster was also applied to the background counts (including normalization with respect to cluster area). Each cluster LF was then summed to produce a composite LF for each radial bin.

Figure 1 shows the composite LF computed for the inner and outer radial regions. It is clear from this figure that a single Schechter function is inadequate to describe the composite LFs. We have therefore used the sum of two Schechter functions to fit the LFs in both cases. For the inner radial bin ( $r \leq r_{200}$ ), we find a faint-end slope of  $\alpha_{inner} = -1.81 \pm 0.02$ . The faint-end slope for the outer radial bin ( $r_{200} \leq r \leq 2r_{200}$ ) was measured to be  $\alpha_{outer} = -2.07 \pm 0.02$ . It is clear from this result that the inner region has a significantly flatter faint-end slope than the outer region.

## 4. Discussion and Conclusions

Schechter (1976) described an empirical function which was shown to provide an adequate fit to a sample of 14 cluster LFs. Many studies have investigated the possibility that the LF is “universal” (e.g., Lugger 1986). The results of several recent studies (e.g., López-Cruz et al. 1997; Driver, Couch, & Phillipps 1998), clearly demonstrate that cluster LFs are not universal but are instead a function of environment (this is really just a re-statement of the density-morphology relation).

The comparison of the composite LFs in this study support the conclusion that cluster LFs are not universal and are in fact dependent upon cluster-centric radius (ie., environment). This result is also consistent with the dwarf galaxy disruption model since one expects that tidal forces acting on dwarf galaxies would be greater near the central regions of clusters. A reduction in the fraction of dwarf galaxies, relative to the remaining galaxy cluster population, would be expected for the inner cluster regions.

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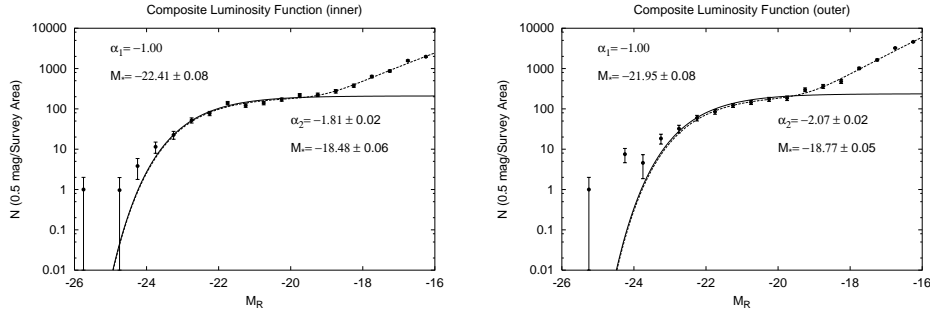


Figure 1. This figure depicts the composite LF for the inner ( $r \leq r_{200}$ ) and outer ( $r_{200} \leq r \leq 2r_{200}$ ) radial bins. The faint-end slope of the inner region is significantly flatter ( $\alpha_{inner} = -1.81 \pm 0.02$ ) than the faint-end slope of the outer region ( $\alpha_{outer} = -2.07 \pm 0.02$ ).